High-Resolution Hydrographic Surveys near the Shelfbreak in the East China Sea: Joint Studies with National Taiwan University as part of the Quantifying, Predicting, and Exploiting Uncertainty DRI

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LONG-TERM GOALS

The long-term goal of this project is to establish major contributors to uncertainty in the prediction of both oceanographic processes and transmission loss for acoustic propagation in shelfbreak regions using in situ field data and regional models.

OBJECTIVES

The objectives of this project were to perform a field experiment in the East China Sea northeast of Taiwan with concurrent oceanographic and acoustic measurements to provide actual measurements to compare with uncertainty predictions from both oceanographic and acoustic propagation models. Key oceanographic processes include Cold Dome formation and maintenance over the outer continental shelf, Kuroshio interactions with the shelf, internal tides, and response to wind-forcing.

APPROACH

G. Gawarkiewicz was the lead U.S. scientist for the QPE Main Field Experiment in August/September, 2009. In conjunction with the lead Taiwanese scientist, Professor Jan Sen of National Taiwan University, an extensive observational program was conducted northeast of Taiwan involving multiple components including measurements of the Kuroshio, large-scale hydrographic surveys to measure the structure and extent of the Cold Dome, moored oceanographic and acoustic measurements, and concurrent SeaSoar surveys and acoustic transmission loss measurements near two contrasting sites near the shelfbreak and at mid-shelf. During the experiment, extensive modeling efforts were directed toward prediction of tidal currents, regional circulation, transmission loss of low-frequency sound energy as well as uncertainty of these predictions.

WORK COMPLETED

During the Main Field Program, Gawarkiewicz was the US lead scientist and Jan Sen of National Taiwan University was the lead Taiwanese scientist for the program as well as joint oceanographic/acoustic operations on the R/V Ocean Researcher I, a Taiwanese research vessel. In

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14. ABSTRACT
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15. SUBJECT TERMS

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addition to coordinating the 14 cruises on 4 different research vessels, Gawarkiewicz oversaw joint operations using the National Taiwan University SeaSoar for high-resolution hydrographic surveys. The SeaSoar operations included ten different surveys focusing near the shelfbreak but also extending onshore as far north as the mid-shelf site at the 110 m isobath and offshore over the continental slope to the 1000 m isobath. Multiple transects along the 130 m isobath just shoreward of the shelfbreak measured thermohaline properties and velocities using the shipboard Acoustic Doppler Current Profiler. Sections in the central portion of the Cold Dome and in a branch of North-Mien Hua Canyon were also sampled. This work was done in collaboration with J. Wang of National Taiwan University and Y.-J. Yang of Chinese Naval Academy, Kaohsiung. During the cruise, mobile acoustic sources and sonobuoys were deployed by OASIS Inc. initially near the two contrasting shelfbreak and mid-shelf sites but later in areas of interest identified from regional numerical models providing both ocean circulation and transmission loss. These models were run by J. Sen at National Taiwan University, P. Lermusiaux at MIT, Y.-T. Lin at WHOI, and K. Heaney at OASIS Inc. Adaptive sampling was performed using as criteria for geographical siting of mobile acoustic source runs the thermohaline structure measured by the SeaSoar as well as the spatial structure of the transmission loss predicted by models.

In addition, mooring arrays were deployed at the two sites of interest at the 110 m and 130 m isobaths. These consisted of three thermistor chains and one bottom-mounted ADCP along with two Single Hydrophone Recording Units (SHRUs) and a horizontal line area. Despite significant fishing activity near the two sites, all moorings were recovered and instruments returned good oceanographic and acoustic data.

RESULTS

The field observations from August/September, 2009, revealed some very interesting processes contributing to variability over the outer shelf and continental slope. First, the first leg of the cruise occurred two weeks after Typhoon Morakot had passed across Taiwan and caused extensive damage through southern Taiwan with heavy rainfall and flooding. In the QPE study area, we observed initially that there was a high degree of small-scale salinity and temperature features likely associated with the typhoon-enhanced river runoff (Figure 1). In addition, there was substantial cooling in the area (up to 6 degrees C. as measured at Pengjia Island) after the typhoon passed by. Just six days later (Figure 2), the salinity variability was much less pronounced and the thermocline structure was more typical of the climatological mean picture.

During the course of the observations from the Ocean Researcher I, the Cold Dome structure also changed substantially. Initially, there were strong cross-slope gradients associated with the offshore edge of the Cold Dome in the southwestern portion of the study area. However, this weakened over time and at the end of the cruise there were not substantial sub-surface temperature gradients normally associated with the Cold Dome. A number of SeaSoar transects were sampled along the 130 m isobath between Mien-Hua Canyon and North Mien-Hua Canyon and we will be calculating cross-shelf heat and salt fluxes to determine offshore influences on the Cold Dome structure and variability. Mapping of the thermohaline structure was concentrated in the vicinity of the on-shelf and shelfbreak sites for examining the impact of oceanographic variability on transmission loss during the first leg of the cruise and adaptive sampling based on both oceanographic and transmission loss predictions during the second leg of the cruise. The adaptive sampling was facilitated by numerical model results being transmitted to the ship. In addition to both nowcast and forecast fields of circulation and transmission loss, uncertainty fields for the oceanographic variables were also received on the ship from P.

Lermusiaux's lab at MIT as well as optimized sampling fields based on transmission loss models generated by K. Heaney of OASIS, Inc. The adaptive sampling concentrated on sampling of high-gradient regions in the boundaries of the Cold Dome as well as in North Mien-Hua Canyon.

IMPACT/APPLICATIONS

The observations and modeling for this field program will be used in further developing tools which estimate the uncertainties in model predictions for both the ocean circulation and acoustic propagation in this region. We expect these tools to be of general use and applicable to other shelfbreak regions. The analysis of this data will also focus on Environmental Keys which are proxies to identify regions of sharp changes in acoustic propagation characteristics which can be simply identified via hydrographic or other environmental data.

RELATED PROJECTS

This work is related to efforts to establish impacts of oceanographic processes on acoustic propagation in the Advanced Wide Aperture Cluster for Surveillance (AWACS) project, which involved field work off New Jersey in conjunction with the Shallow Water 06 experiment.

PUBLICATIONS

Linder, C., G. Gawarkiewicz, J.-H. Tai, and T.-Y. Tang. A seasonal climatology of Taiwan Strait and the northeast South China Sea. Terrestrial, Atmospheric, and Ocean Sciences, submitted.

G. Gawarkiewicz, F. Bahr, C. Marquette, J. Sen, C.-F. Chen, H.-C. Chang, Y.-S. Chiu, Y.-Y. Chang, D. Morton, P. Abbot, K. Heaney, C. Emerson, T. Abbot, Y.-J. Yang, L. Centurioni, P. Niiler, C. McCall, J. Wang, B. Wang, Y.-F. Ma, C.-C. Lai, S.-C. Shie, T.-C. Liu, P. Lermusiaux, P. Haley, W. Leslie, J. Xu, E. Heubel. Quantifying, Predicting, and Exploiting Uncertainty (QPE), 2008 Pilot Experiment: August 22-September 11, 2008. Technical Report.

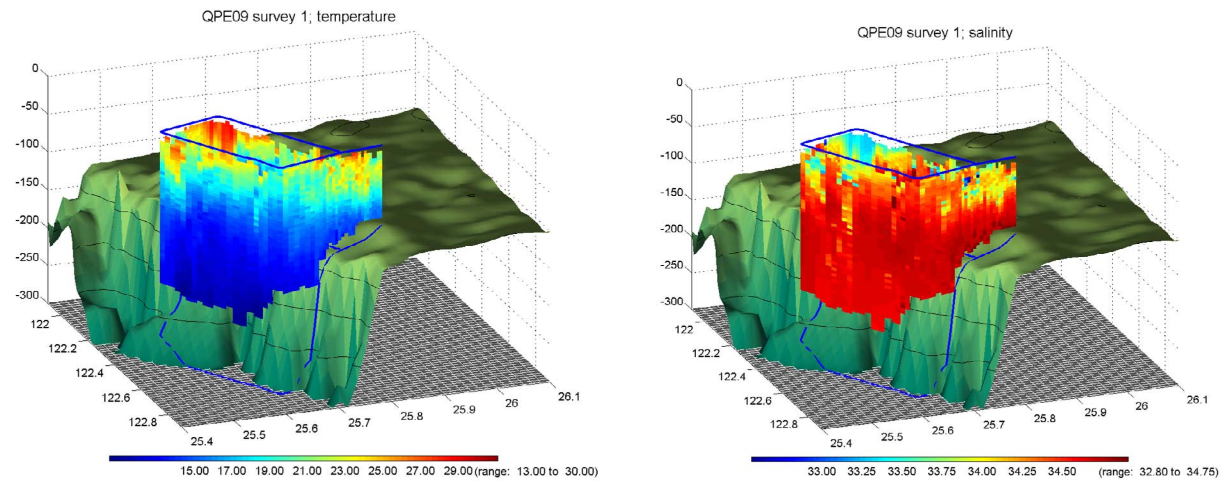

Figure 1- A plot of temperature (left panel) and salinity (right panel) from the East China Sea on August 25, 2009, shortly after Typhoon Morakot showing substantial small scale variability and a very weak thermocline.

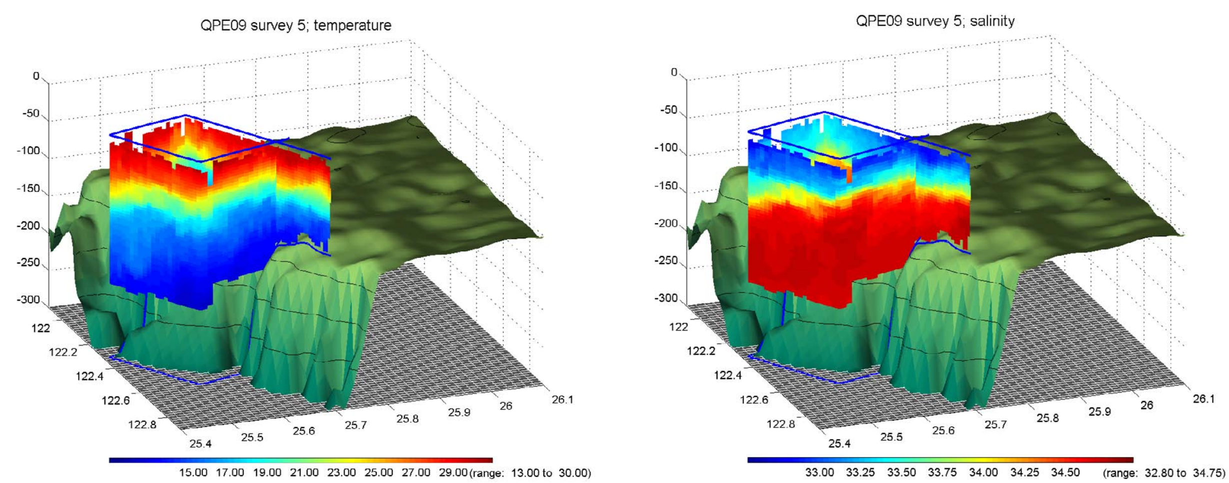

Figure 2- A plot of temperature (left panel) and salinity (right panel) from the East China Sea on August 31, 2009. Note the fully developed thermocline and halocline more typical of summer conditions.